General Biology

Course No: BNG2003
Credits: 3.00

2c. Carbon and the Molecular Diversity of Life

Prof. Dr. Klaus Heese

- Carbon — The Backbone of Biological Molecules
- All living organisms
  - are made up of chemicals based mostly on the element carbon

- **Organic chemistry is the study of carbon compounds**
- Organic compounds range from simple molecules to colossal ones
- The concept of vitalism
  - Is the idea that organic compounds arise only within living organisms
  - Was disproved when chemists synthesized the compounds in the laboratory

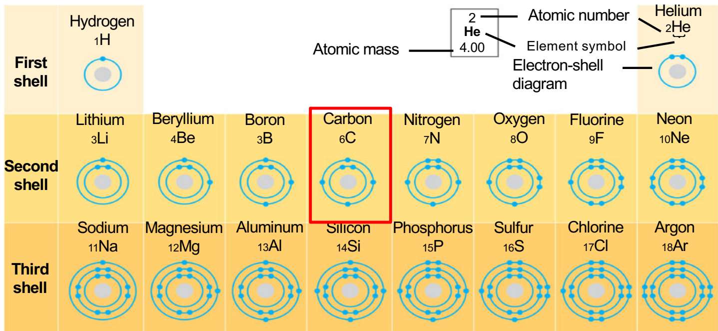
EXPERIMENT In 1953, Stanley Miller simulated what were thought to be environmental conditions on the lifeless, primordial Earth. As shown in this recreation, Miller used electrical discharges (simulated lightning) to trigger reactions in a primitive "atmosphere" of H_2O, H_2, NH_3 (ammonia), and CH_4 (methane)—some of the gases released by volcanoes.

RESULTS A variety of organic compounds that play key roles in living cells were synthesized in Miller's apparatus.

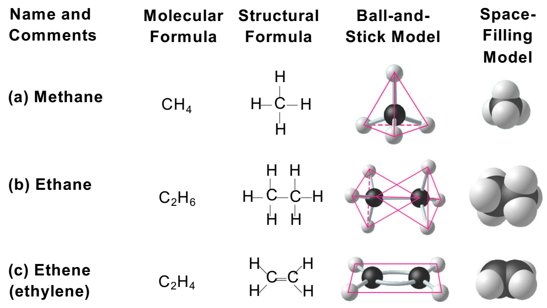
CONCLUSION Organic compounds may have been synthesized abiotically on the early Earth, setting the stage for the origin of life. (We will explore this hypothesis in more detail in Chapter 26.)

- **Carbon** atoms can form diverse molecules by **bonding to four other atoms**
- The Formation of Bonds with Carbon:
- Carbon has four valence electrons
- This allows it to form four covalent bonds with a variety of atoms

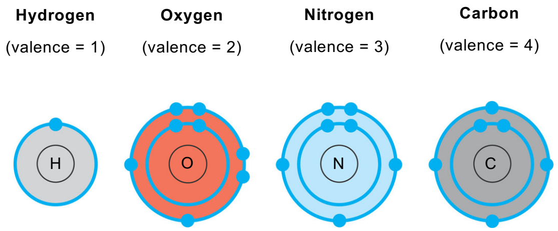
- The periodic table of the elements
  - shows the electron distribution for all the elements



- The bonding versatility of Carbon
  - allows it to form many diverse molecules, including carbon skeletons

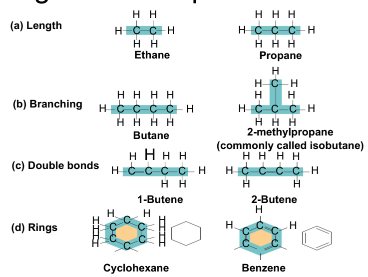


- The electron configuration of carbon
  - gives it covalent compatibility with many different elements

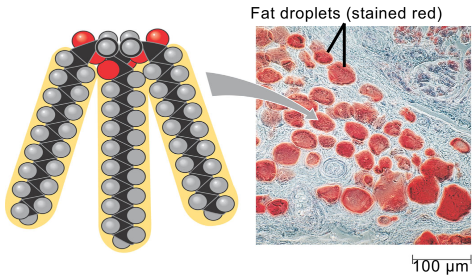


Molecular Diversity Arising from Carbon Skeleton Variation

- **Carbon chains**
  - form the skeletons of most organic molecules
  - vary in length and shape



- **Hydrocarbons:** Are molecules consisting of only carbon and hydrogen
  - are found in many of a cell's **organic molecules**

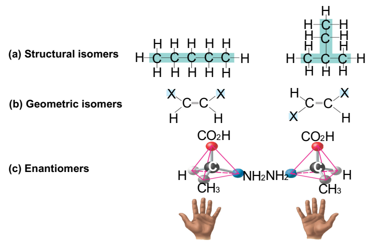


(a) A fat molecule (b) Mammalian adipose cells

Isomers

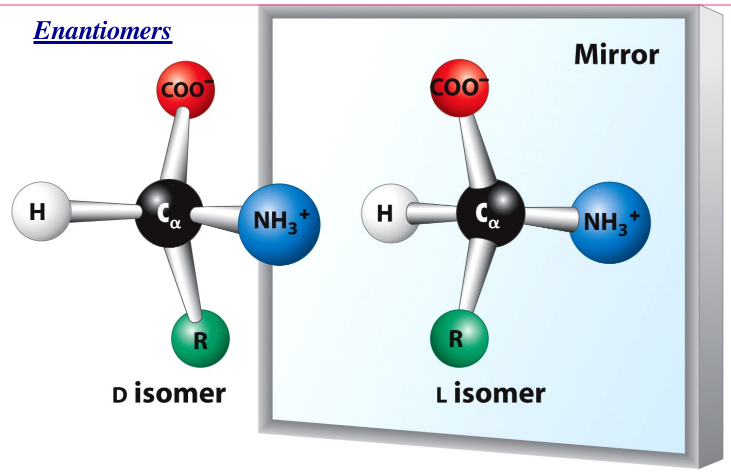
are molecules with the same molecular formula but different structures and properties

- **three types** of isomers are
  - Structural
  - Geometric
  - Enantiomers



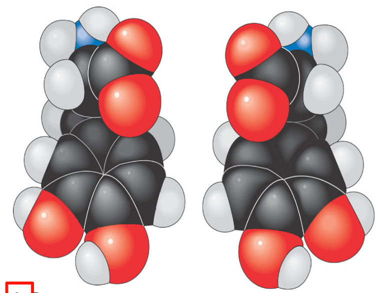
Special feature of molecules that define cell (function) which defines life.

Enantiomers



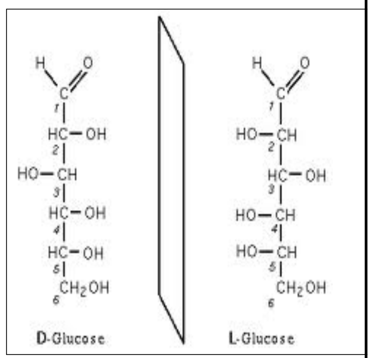
Enantiomers are chiral molecules that are *mirror images* of one another. Furthermore, the molecules are *non-superimposable* on one another. This means that the molecules cannot be placed on top of one another and give the same molecule.

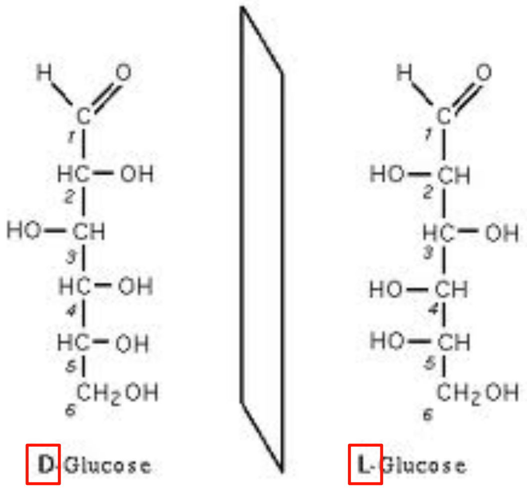
- Enantiomers
  - are important in the pharmaceutical industry



L-Dopa
(effective against Parkinson's disease)

D-Dopa
(biologically inactive)

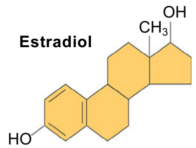


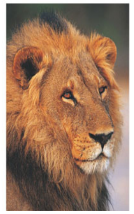


The **Functional Groups** Most Important in the Chemistry of Life

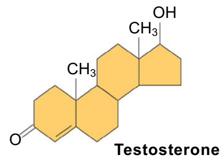
- Functional groups are the chemically reactive groups of atoms within an organic molecule
- Functional groups are the parts of molecules involved in chemical reactions and give organic molecules distinctive chemical properties

Female lion





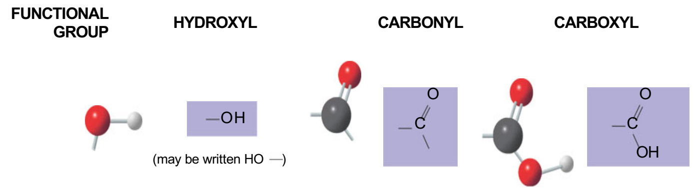
Male lion



The **Functional Groups** Most Important in the Chemistry of Life

- **Six** functional groups of organic compounds are important in the chemistry of life
  - Hydroxyl
  - Carbonyl
  - Carboxyl
  - Amino
  - Sulfhydryl
  - Phosphate

Six functional groups of organic compounds are important in the **chemistry of life**: 1. Hydroxyl, 2. Carbonyl, 3. Carboxyl, 4. Amino, 5. Sulfhydryl, 6. Phosphate



STRUCTURE	In a hydroxyl group (—OH), a hydrogen atom is bonded to an oxygen atom, which in turn is bonded to the carbon skeleton of the organic molecule. (Do not confuse this functional group with the hydroxide ion, OH^-.)	The **carbonyl group** (>CO) consists of a carbon atom joined to an oxygen atom by a double bond.	When an oxygen atom is double-bonded to a carbon atom that is also bonded to a hydroxyl group, the entire assembly of atoms is called a **carboxyl group** (—COOH).

Six functional groups of organic compounds are important in the **chemistry of life**: 1. Hydroxyl, 2. Carbonyl, 3. Carboxyl, 4. Amino, 5. Sulfhydryl, 6. Phosphate

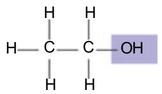
NAME OF COMPOUNDS

Alcohols (their specific names usually end in *-ol*)

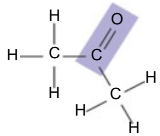
Ketones if the carbonyl group is within a carbon skeleton
Aldehydes if the carbonyl group is at the end of the carbon skeleton

Carboxylic acids, or organic acids

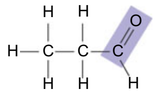
EXAMPLE



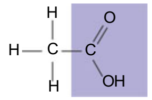
Ethanol, the alcohol present in alcoholic beverages



Acetone, the simplest ketone



Propanal, an aldehyde



Acetic acid, which gives vinegar its sour tatste

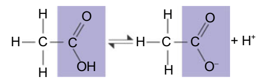
Six functional groups of organic compounds are important in the **chemistry of life**: 1. Hydroxyl, 2. Carbonyl, 3. Carboxyl, 4. Amino, 5. Sulfhydryl, 6. Phosphate

FUNCTIONAL PROPERTIES

- Is polar as a result of the electronegative oxygen atom drawing electrons toward itself.
- Attracts water molecules, helping dissolve organic compounds such as sugars.

- A ketone and an aldehyde may be structural isomers with different properties, as is the case for acetone and propanal.

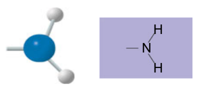
- Has acidic properties because it is a source of hydrogen ions. The covalent bond between oxygen and hydrogen is so polar that hydrogen ions (H^+) tend to dissociate reversibly; for example,



- In cells, found in the ionic form, which is called a carboxylate group.

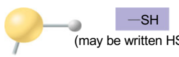
Six functional groups of organic compounds are important in the **chemistry of life**: 1. Hydroxyl, 2. Carbonyl, 3. Carboxyl, 4. Amino, 5. Sulfhydryl, 6. Phosphate

AMINO



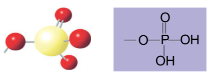
The **amino group** (—NH_2) consists of a nitrogen atom bonded to two hydrogen atoms and to the carbon skeleton.

SULFHYDRYL



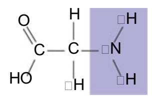
The **sulfhydryl group** consists of a sulfur atom bonded to an atom of hydrogen; resembles a hydroxyl group in shape.

PHOSPHATE

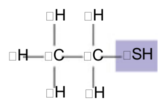


In a **phosphate group,** a phosphorus atom is bonded to four oxygen atoms; one oxygen is bonded to the carbon skeleton; two oxygens carry negative charges; abbreviated (P). The phosphate group (—OPO_3^{2-}) is an ionized form of a phosphoric acid group (—OPO_3H_2; note the two hydrogens).

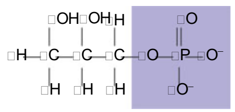
Six functional groups of organic compounds are important in the **chemistry of life**: 1. Hydroxyl, 2. Carbonyl, 3. Carboxyl, 4. Amino, 5. Sulfhydryl, 6. Phosphate



Glycine



Ethanethiol

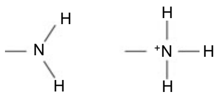


Glycerol phosphate

Because it also has a carboxyl group, glycine is both an amine and a carboxylic acid; compounds with both groups are called amino acids.

Six functional groups of organic compounds are important in the **chemistry of life**: 1. Hydroxyl, 2. Carbonyl, 3. Carboxyl, 4. Amino, 5. Sulfhydryl, 6. Phosphate

- Acts as a base; can pick up a proton from the surrounding solution:



(nonionized) (ionized)

- Ionized, with a charge of 1+, under cellular conditions.

- Two sulfhydryl groups can interact to help stabilize protein structure (see Figure 5.20).

- Makes the molecule of which it is a part an anion (negatively charged ion).
Can transfer energy between organic molecules.

The Chemical Elements of Life: *A Review*

- The versatility of carbon
  - makes the great diversity of organic molecules